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Min et al.

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(54) **METHOD OF FORMING SPACER IN FLAT PANEL DISPLAY**

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(22) Filed: **Jun. 11, 2002**

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(30) **Foreign Application Priority Data**

Jun. 12, 2001 (KR) 2001-32950

(51) **Int. Cl.**[7] **H01J 9/00**; H01J 9/24

(52) **U.S. Cl.** **445/24**; 445/24; 445/25; 156/1; 156/60; 156/275.3; 156/275.5; 156/275.7; 428/343; 428/345; 427/207.1

(58) **Field of Search** 445/24, 25; 156/1, 156/60, 370.1, 275.1, 275.3, 275.5, 275.7, 272.2, 273.5; 428/343, 345; 313/292; 427/207.1; 349/187

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,924,243	A *	5/1990	Sato et al.	349/187
5,385,499	A	1/1995	Ogawa et al.	
5,486,126	A	1/1996	Cathey et al.	
5,545,280	A *	8/1996	Wenz	427/207.1
5,558,732	A	9/1996	Hamon	
5,788,550	A	8/1998	Jones et al.	
5,919,606	A	7/1999	Kazlas et al.	
6,031,593	A *	2/2000	Morikawa et al.	349/187
6,312,546	B1 *	11/2001	Bannister et al.	156/230

FOREIGN PATENT DOCUMENTS

EP	0 616 354 A2		9/1994	
GB	2 327 768 A2		2/1999	
JP	03064736 A	*	3/1991	G02F/1/1339
JP	2001130009 A	*	5/2001	B41J/2/16
WO	WO 98/40901		9/1998	

* cited by examiner

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(57) **ABSTRACT**

A forming method of spacers in a flat panel display is provided. The method includes the steps of preparing a plurality of spacers in a predetermined shape, preparing a substrate on which the spacers are to be attached in the flat panel display, applying a photosensitive adhesive material on an upper surface of the substrate to a predetermined thickness, aligning the spacers on the substrate to attach the spacers by using the photosensitive adhesive material, radiating light onto the substrate from above the substrate to expose portions of the photosensitive adhesive material without the spacers, and removing the exposed portions of the photosensitive adhesive material. Therefore, the spacers are fixed on the substrate by the photosensitive adhesive material located under the spacers. According to the provided method of forming spacers, the spacers are fixed on the substrate by a mounting process using a jig, a temporary exposing process, and a developing process. In this case, the spacers are simultaneously placed on the substrate by the jig so that the spacers can be precisely aligned. The characteristic of the provided method of forming spacers is very effective in mass production of flat panel displays.

18 Claims, 8 Drawing Sheets

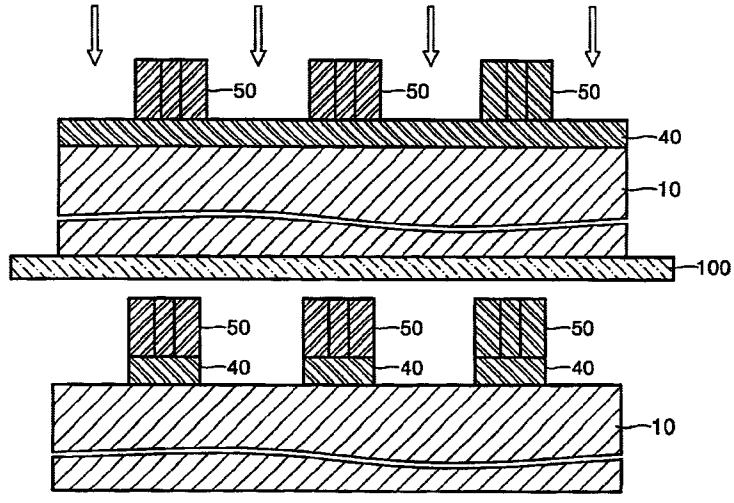


FIG. 1

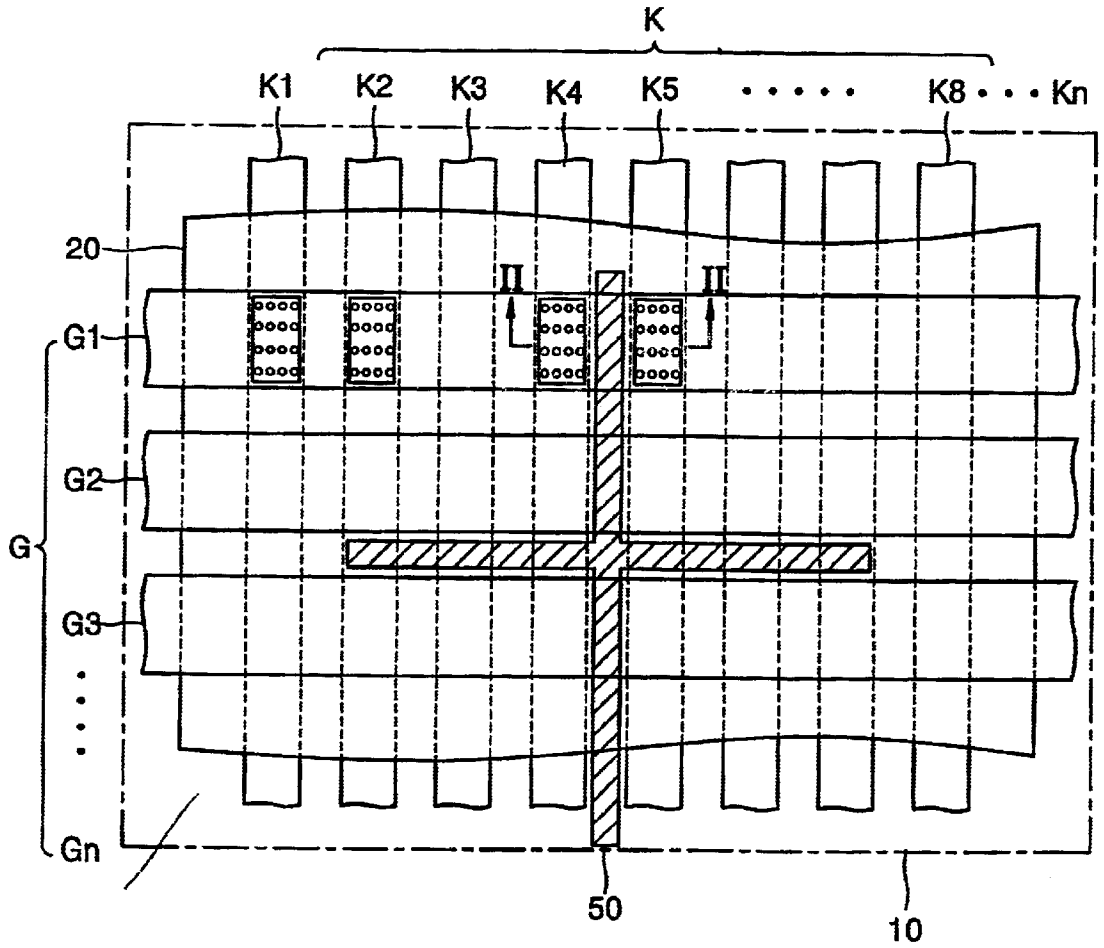


FIG. 2

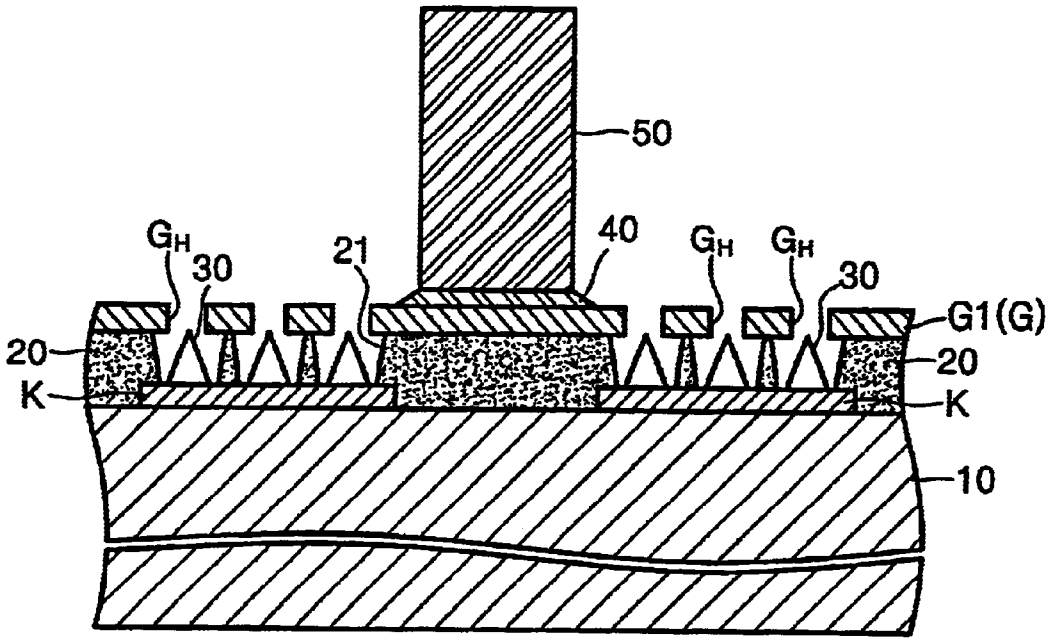


FIG. 3

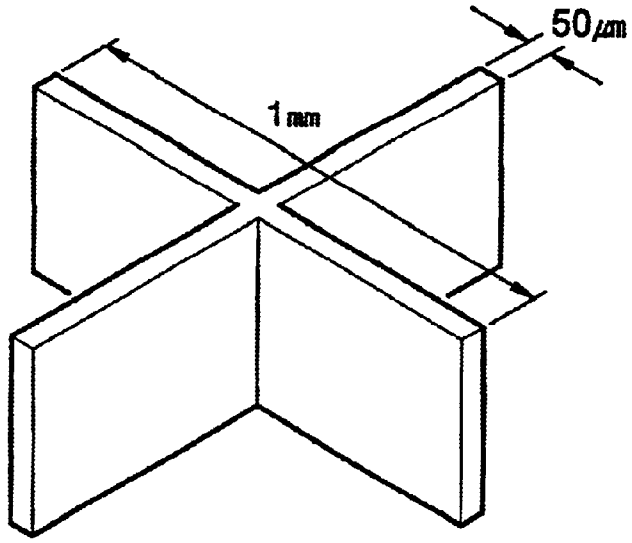


FIG. 4

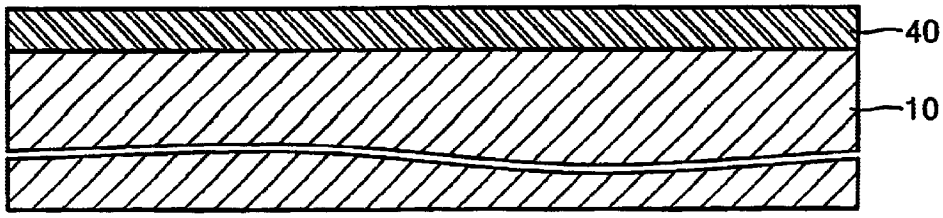


FIG. 5

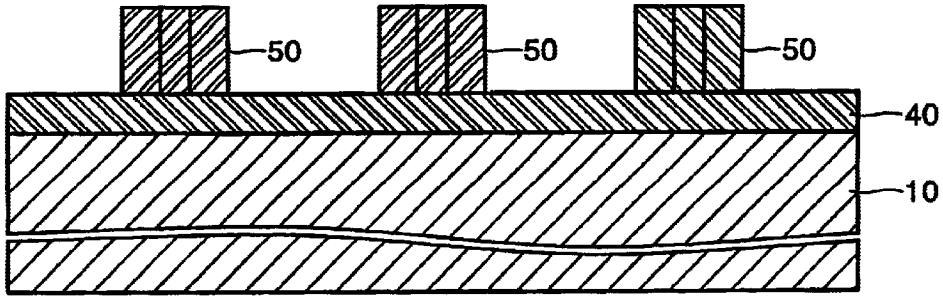


FIG. 6

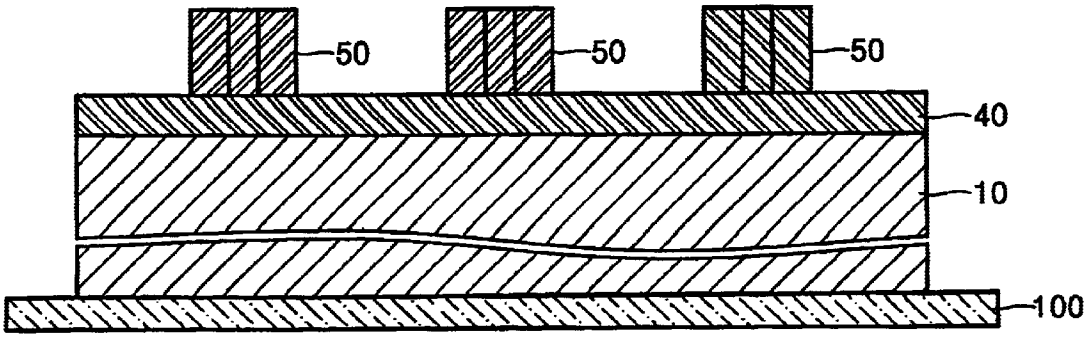


FIG. 7

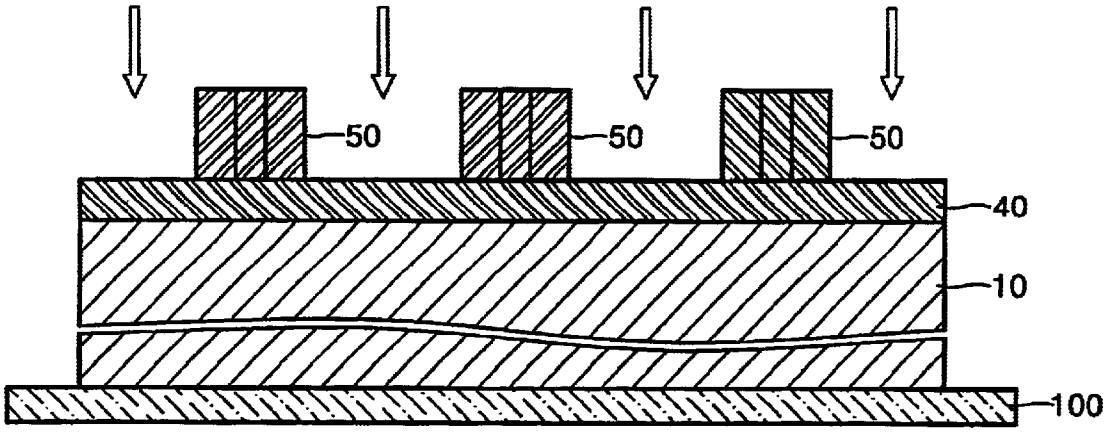


FIG. 8

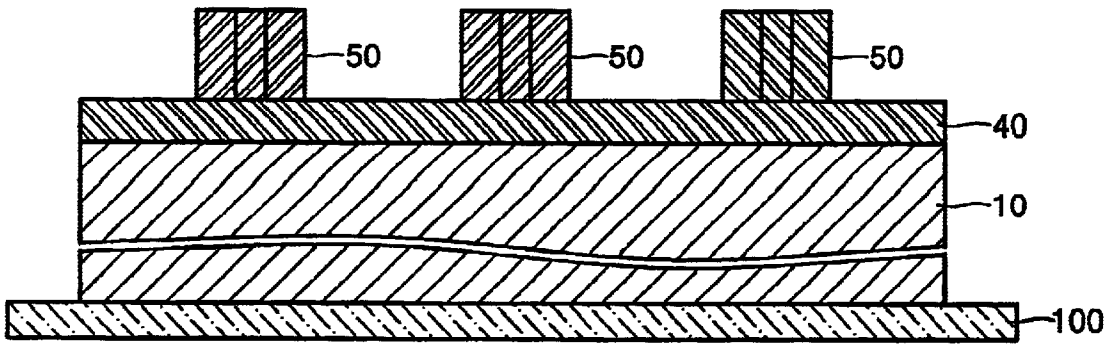


FIG. 9

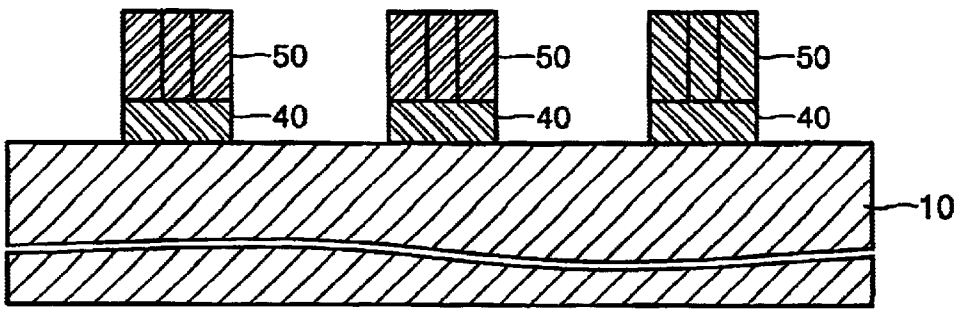


FIG. 10

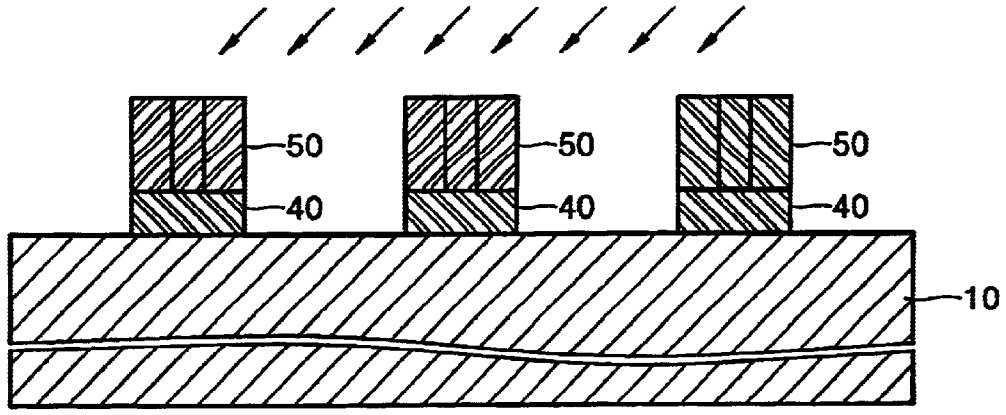


FIG. 11

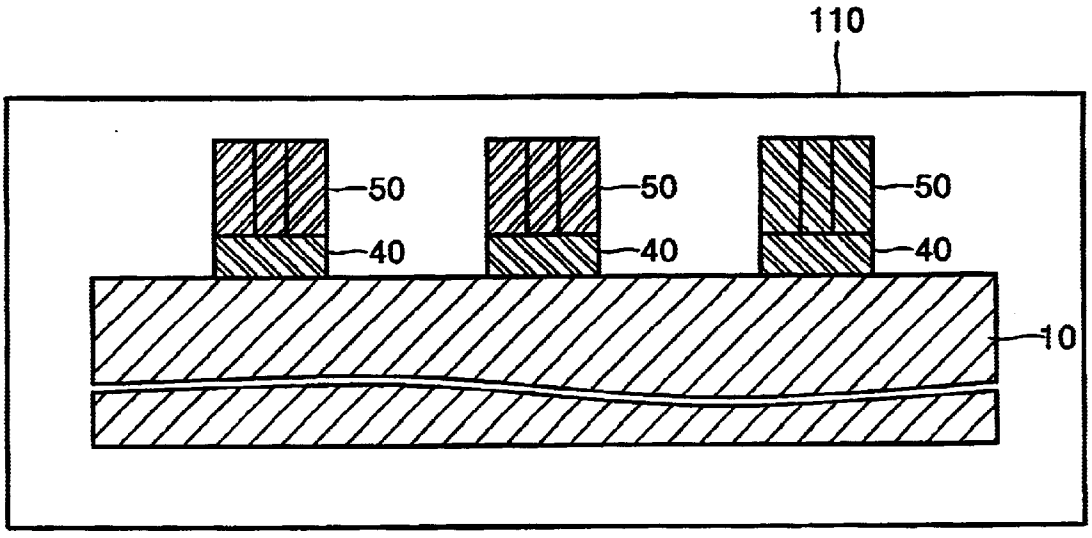


FIG. 12

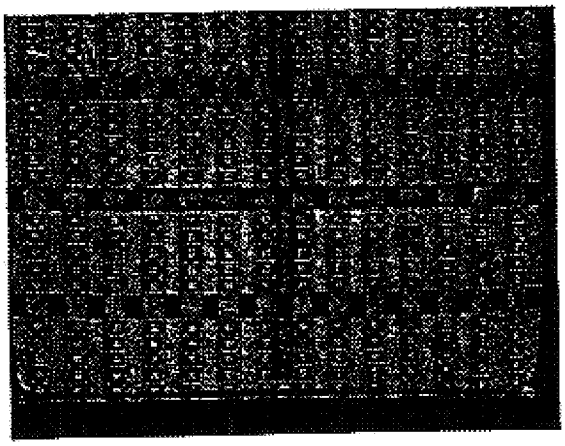


FIG. 13

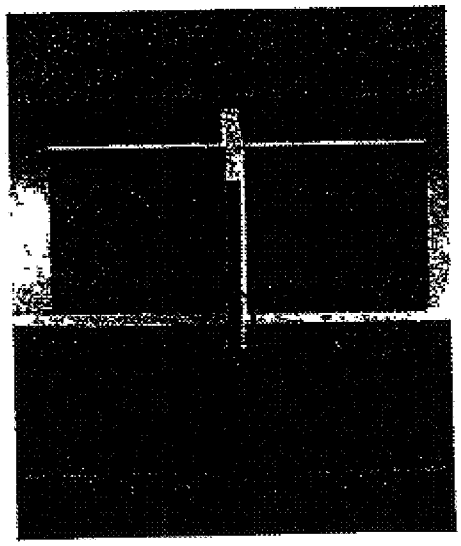


FIG. 14

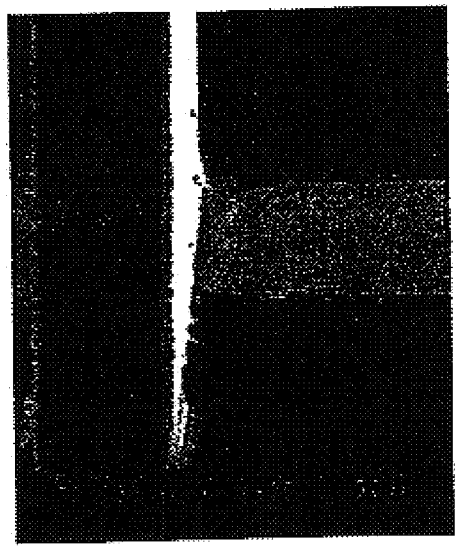


FIG. 15

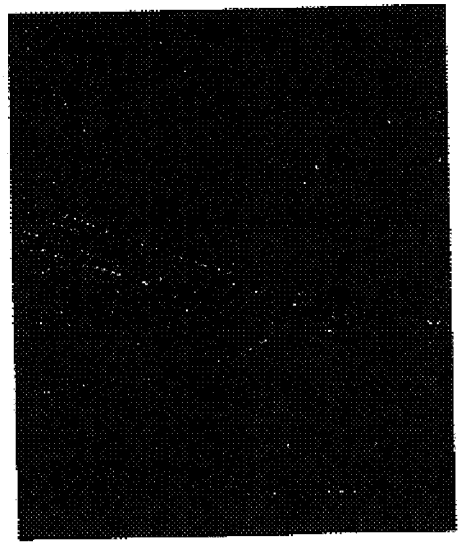
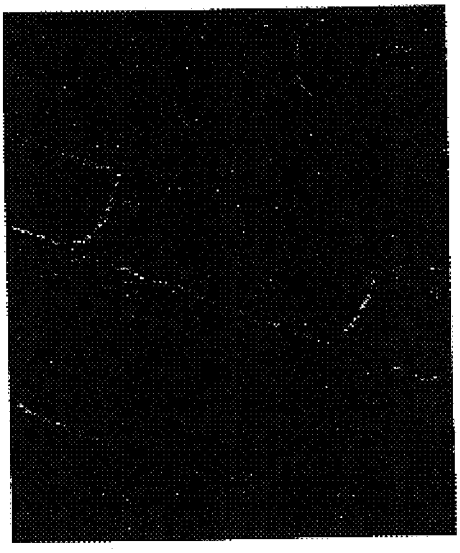


FIG. 16

FIG. 17



METHOD OF FORMING SPACER IN FLAT PANEL DISPLAY

Priority is claimed to Patent Application Number 2001-32950 filed in Republic of Korea on Jun. 12, 2001, herein incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to method of forming spacers in a flat panel display, and more particularly, to a method of forming spacers in a flat panel display requiring an inner vacuum such as a field emission display (FED).

2. Description of the Related Art

A flat panel display such as an FED having operating characteristics like electron emission in a vacuum space and luminescence due to excitation by the emitted electrons, includes a front plate, a rear plate, and spacers therebetween.

The flat panel display having an internal vacuum space requires a component for protecting the vacuum space and a structure for supporting the vacuum space from atmospheric pressure. The spacers are located between the front plate and the rear plate for maintaining a constant gap between the front and rear plates against the atmospheric pressure applied from outside.

In the case of a conventional FED, anode electrodes and a fluorescent layer are formed on the front plate, and electron emitting sources such as micro-tips or carbon nanotubes (CNTs), and cathodes and gate electrodes for controlling electron emission, are stacked on the rear plate.

Consequently, if the front or rear plate is deformed by the atmospheric pressure and other external pressure, the components on the front and rear plates are damaged. Especially, if the gap between the front and rear plates is changed, the emission and control of electrons will likely be severely disturbed.

Therefore, the gap between the front and rear plates has to be maintained firmly and stably in a flat panel display such as an FED. Moreover, the spacers between the front and rear plates have to be located at precise locations that do not trouble image display so as not to affect a displayed image.

For these reasons, in conventional methods of manufacturing a flat panel display, the spacers are individually formed or are stacked in a print manner. In the method of individually forming the spacers, an adhesive is applied to the spacers and the spacers are aligned and fixed onto a target at predetermined locations, for example an inner surface of the rear plate. The method includes a process of applying the adhesive, a process of aligning the spacers, and a process of loading the spacers, and thus takes a long time. Also, the rear plate is easily contaminated by an error in aligning the spacers resulting in spread of the adhesive applied to the spacers. Moreover, in the case of an FED, the precise alignment of the spacers between black matrixes of the anodes formed on an inner surface of the front plate requires expensive high-precision equipment.

Another problem is that adhesive is applied to the spacers and then the spacers are attached to the target. However, it is difficult to decide which adhesive to use for the processes and to form a pattern size of not greater than 50 μm, which is a minimum value for a printing mask.

Furthermore, a printing forming method of the spacers requires repetitive printing processes for achieving high-definition and has a limit in height with high aspect ratio.

SUMMARY OF THE INVENTION

To solve the above-described problems, it is an objective of the present invention to provide a method of forming spacers in a flat panel display which precisely aligns and fixes the spacers in the flat panel display and saves time and effort in forming the spacers by simplifying processes.

To accomplish the objective of the present invention, there is provided a method of forming spacers in a flat panel display comprising preparing a plurality of spacers in a predetermined shape, preparing a substrate on which the spacers are to be attached in the flat panel display, applying a photosensitive adhesive material on an upper surface of the substrate to a predetermined thickness, aligning the spacers on the substrate to attach the spacers by using the photosensitive adhesive material, radiating light onto the substrate from above the substrate to expose portions of the photosensitive adhesive material without the spacers, and removing the exposed portions of the photosensitive adhesive material, wherein the spacers are fixed on the substrate by the photosensitive adhesive material located under the spacers.

In an embodiment of the present invention, a process of soft baking the photosensitive adhesive material by using a thermal source may be further included before radiating light onto the substrate.

Also, a drying process for drying the substrate and an annealing process for annealing the adhesive material under the spacers by which the spacers are preferably attached to the substrate are further included before removing the exposed portions of the adhesive material.

A method of forming spacers in a flat panel display according to an embodiment of the present invention will be described in detail below with reference to the accompanying drawings. In the described embodiment of the present invention, the flat panel display is a field emission display (FED) that requires an inner vacuum space and spacers between front and rear plates.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objective and advantages of the present invention will become more apparent by describing in detail a preferred embodiment thereof with reference to the attached drawings in which:

FIG. **1** is a partial plan view of a field emission display (FED) in which spacers are fixed according to the present invention;

FIG. **2** is a sectional view cut along line II—II of FIG. **1**;

FIG. **3** is a schematic perspective view of a spacer according to the present invention;

FIGS. **4** through **11** illustrate processes of forming spacers according to an embodiment of the present invention;

FIG. **12** is a scanning electron microscope (SEM) photograph of a portion of an FED on which a spacer is mounted according to the present invention;

FIG. **13** is an SEM photograph illustrating an enlarged view of a spacer portion of an FED having spacers according to the present invention;

FIG. **14** is an enlargement of a portion of FIG. **13** encircled by a dotted line;

FIG. **15** is an SEM photograph illustrating an enlarged view of a portion on which a spacer has been fixed according to the present invention and forcibly separated to examine the thickness of an adhesive layer for fixing the spacer;

FIG. **16** is an enlargement of a portion of FIG. **15** encircled by a dotted line; and

FIG. **17** is an enlargement of a portion of FIG. **16** encircled by a dotted line.

DETAILED DESCRIPTION OF THE INVENTION

The principle structure of a field emission display (FED), such as a flat panel display, in which spacers are formed according to the present invention will be described.

FIG. **1** is a partial plan view of a rear plate (substrate) **10** of an FED having electron emission sources. FIG. **2** is a sectional view cut along line II—II of FIG. **1**.

Referring to FIGS. **1** and **2**, a plurality of cathode electrodes K_1, K_2, K_3, . . . K_n, and K is arranged in a first direction, namely, a longitudinal direction in FIG. **1**, on the substrate **10** with a predetermined gap therebetween. A gate insulating layer **20** is formed on the cathode electrodes K for arranging a plurality of gate electrodes G_1, G_2, G_3, . . . , G_n, and G on the gate insulating layer **20** in a second direction, namely, a traverse direction in FIG. **1** that is perpendicular to the first direction. On the gate insulating layer **20**, through holes **21** are formed for providing hollow portions in which micro-tips **30** are located on the cathode electrodes. A plurality of gate holes G_H through which electrons penetrate is densely formed on the gate electrodes G at portions where the gate and cathode electrodes G and K cross. The gate holes G_H are formed to correspond to the through holes **21** of the gate insulating layer **20**. According to the structure described above, an electron emission structure with a plurality of micro-tips is arranged in one pixel, which is a portion where the gate and cathode electrodes G and K cross. On the structure, cross shape spacers **50** are fixed. The spacers **50** are arranged in gap portions between the gate and cathode electrodes G and K, namely, non-pixel regions from which electrons are not emitted. The spacers **50** are fixed on upper surfaces of the gate electrodes G and the gate insulating layer **20** by an adhesive layer **40**. FIG. **2** illustrates the spacer **50** fixed on the gate electrode G by the adhesive layer **40**. The adhesive layer **40** is formed of a photoresist such as polyimide.

The thickness of the spacers **50** is about 50 μm, which is the same as or smaller than the gaps between the gate electrodes G and between the cathode electrodes K. The length of the spacers **50** in one direction is about 1 mm. The spacers **50** are formed of a general soda lime glass.

A method of forming spacers in a flat panel display according to the present invention will now be described with reference to FIGS. **4** through **11**.

The substrate **10** having the cathode electrodes K, the gate electrodes G, and the gate insulating layer **20** for emitting electrons as shown in FIGS. **1** and **2** is prepared. A plurality of spacers **50** is prepared for being arranged on one substrate **10**. The elements formed on the substrate **10**, such as the cathode electrodes, are omitted in FIGS. **4** through **11** for convenience.

Referring to FIG. **4**, a positive photoresist like polyimide is spread to a predetermined thickness, for example, 3 μm, on the substrate **10** having the cathode electrodes K, the gate electrodes G, and the gate insulating layer **20** so that the adhesive layer **40** is formed. It is preferable that the adhesive layer **40** is formed by a general spin coating method. After the adhesive layer **40** is formed on the substrate **10**, the adhesive layer **40** physically and chemically protects the components on the substrate **10** in following processes of forming the spacer. Accordingly, the micro-tips and the gate electrodes are protected from external impact.

Referring to FIG. **5**, a plurality of spacers **50** is arranged on the adhesive layer **40**. In this case, the spacers **50** are located at regions where they do not interfere with electron emission. A jig is used for simultaneously placing a plurality of spacers **50** on the substrate **10**.

Referring to FIG. **6**, the substrate **10** is placed on a heating unit such as a hot plate **100** for soft baking the adhesive layer **40**.

Referring to FIG. **7**, ultraviolet rays are radiated from above the substrate **10** for exposing the adhesive layer **40**. Accordingly, portions of the adhesive layer **40** on which the spacers **50** are not located are exposed.

Referring to FIG. **8**, the substrate **10** is placed on the hot plate **100** for performing a post exposure bake. As a result, the polyimide which forms the adhesive layer **40** is hardened, and the spacers **50** are firmly fixed on the substrate **10** by the adhesive layer **40**.

Referring to FIG. **9**, the adhesive layer **40** is developed for removing the exposed portions. This process is a kind of developing process performed in general photolithography by using an etchant such as a solution for dissolving the exposed portions of the adhesive layer **40**. After the developing process, cleaning and rinsing processes are performed for removing contaminants such as remaining organic material.

Referring to FIG. **10**, air is blown onto the substrate **10** at an oblique angle. Accordingly, the cathode electrodes K, the gate electrodes G, the gate insulating layer **20**, and the spacers **50** fixed on the gate insulating layer **20** by the adhesive layer **40** are dried.

Referring to FIG. **11**, the substrate **10** is heated in a vacuum chamber **110** at a temperature of about 350° C. thereby performing a vacuum annealing process. As a result, the substrate of the flat panel display having the spacers is obtained.

A portion of the FED substrate having the spacers formed by the above-described method is measured by scanning electron microscope (SEM) for examining the actual resulting FED substrate.

FIG. **12** is a planar SEM photograph of a portion of the substrate having a spacer. In FIG. **12**, the cross shape spacer is not prominent because the spacer is formed of a transparent material through which a lower pattern is seen. When the photograph is examined very carefully, a slightly darkened cross-shaped portion reveals the spacer.

FIG. **13** is an SEM photograph illustrating an enlarged view of a spacer formed on a substrate according to the present invention, and FIG. **14** is an enlarged view of the portion of FIG. **13** encircled by a dotted line. As shown in FIGS. **13** and **14**, the adhesive layer is spread around the base of the spacer.

FIGS. **15** through **17** illustrate a portion in which the spacer has been fixed and after forcibly separated to examine the thickness of the adhesive layer. FIG. **15** is an SEM photograph of the portion in which the spacer has been fixed, FIG. **16** is an enlargement of a portion encircled by dotted lines in FIG. **15**, and FIG. **17** is an enlargement a portion encircled by dotted lines in FIG. **16**.

As shown in FIGS. **15** through **17**, the adhesive layer has fixed the spacer with a uniform thickness. Especially, an uneven section at a connecting portion of the adhesive layer in FIG. **17** indicates that the spacer has been firmly fixed by the adhesive layer.

As described above, the spacers are formed on the substrate of a flat panel display by a photolithography method for firmly fixing the spacers on the substrate. Moreover, the adhesive layer is formed at portions for fixing the spacers and does not remain on other portions. Accordingly, in

forming the adhesive layer for fixing the spacers, the spacers for maintaining a gap between the front and rear plates in the flat panel display are used as a mask in the photolithography process, thereby causing the adhesive layer to remain at predetermined portions. In addition, the spread state of the adhesive layer on the entire surface of the substrate is maintained until the developing process, thereby protecting the elements of the flat panel display such as the micro-tips and the gate electrodes.

According to the present invention, spacers are fixed on a substrate by a mounting process using a jig, a temporary exposing process, and a developing process. In this case, the spacers are simultaneously placed on the substrate by the jig so that the spacers can be precisely aligned. The characteristic of the present invention is very effective in mass production of flat panel displays.

According to the present invention, a photoresist like polyimide is used as an adhesive so that main elements formed on the substrate are physically and chemically protected in spacer forming processes. As a result, the elements of the flat panel display such as micro-tips and gate electrodes are protected from external impact.

While this invention has been particularly shown and described with reference to an FED, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. For example, a method of forming spacers according to the present invention can be applied to any flat panel display requiring spacers, especially a flat panel display requiring very precise alignment and firm fixing force. Accordingly, the flat panel display defined in the appended claims is not limited to an FED, and the method of forming spacers in any kind of flat panel display is within the spirit and scope of the invention so far as the technical characteristics of the prevent invention as defined by the appended claims are used.

What is claimed is:

1. A method of forming spacers in a flat panel display comprising:

preparing a plurality of spacers in a predetermined shape;

preparing a substrate on which the spacers are to be attached in the flat panel display;

applying a photosensitive adhesive material on an upper surface of the substrate to a predetermined thickness;

aligning the spacers on the substrate to attach the spacers by using the photosensitive adhesive material;

radiating light onto the substrate from above the substrate to expose portions of the photosensitive adhesive material without the spacers; and

removing the exposed portions of the photosensitive adhesive material,

wherein the spacers are fixed on the substrate by the photosensitive adhesive material located under the spacers.

2. The method of forming spacers in a flat panel display of claim **1**, wherein a process of soft baking the photosensitive adhesive material by using a thermal source is further included before radiating light onto the substrate.

3. The method of forming spacers in a flat panel display of claim **1**, wherein a drying process for drying the substrate and an annealing process for annealing the adhesive material under the spacers by which the spacers are attached to the substrate are further included before removing the exposed portions of the adhesive material.

4. The method of forming spacers in a flat panel display of claim **2**, wherein a drying process for drying the substrate and an annealing process for annealing the adhesive material under the spacers by which the spacers are attached to the substrate are further included before removing the exposed portions of the adhesive material.

5. The method of forming spacers in a flat panel display of claim **1**, wherein the spacers are formed in a cross shape.

6. The method of forming spacers in a flat panel display of claim **2**, wherein the spacers are formed in a cross shape.

7. The method of forming spacers in a flat panel display of claim **3**, wherein the spacers are formed in a cross shape.

8. The method of forming spacers in a flat panel display of claim **4**, wherein the spacers are formed in a cross shape.

9. The method of forming spacers in a flat panel display of claim **1**, wherein the adhesive layer is formed of polyimide.

10. The method of forming spacers in a flat panel display of claim **2**, wherein the adhesive layer is formed of polyimide.

11. The method of forming spacers in a flat panel display of claim **7**, wherein the adhesive layer is formed of polyimide.

12. The method of forming spacers in a flat panel display of claim **8**, wherein the adhesive layer is formed of polyimide.

13. The method of forming spacers in a flat panel display of claim **1**, wherein the substrate is a rear plate of a field emission display (FED) including a field emission structure.

14. The method of forming spacers in a flat panel display of claim **2**, wherein the substrate is a rear plate of a field emission display (FED) including a field emission structure.

15. The method of forming spacers in a flat panel display of claim **7**, wherein the substrate is a rear plate of a field emission display (FED) including a field emission structure.

16. The method of forming spacers in a flat panel display of claim **8**, wherein the substrate is a rear plate of a field emission display (FED) including a field emission structure.

17. The method of forming spacers in a flat panel display of claim **3**, wherein the substrate is a rear plate of an FED including a field emission structure.

18. The method of forming spacers in a flat panel display of claim **4**, wherein the substrate is a rear plate of an FED including a field emission structure.

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